In the United States Patent and Trademark Office

In re application of)
ANDRE BEAUDIN et al.)
Serial No. 09/626,593) GROUP ART UNIT: 2634
Filed: 27 July, 2000) Examiner: David B. Lugo
For: Spatial Diversity Wireless Communications (Radio) Receiver)

Commissioner of Patents and Trademarks
Washington, D.C. 20231

DECLARATION UNDER 37 C.F.R. § 1.132

I, Dr. Jean-Rene Larocque, Ing., hereby declare and say:

1. I am a citizen of Canada and I reside at 113 Devon Road, Beaconsfield, Quebec, Canada.

2. I am an engineer employed with Dataradio Inc., of Montreal, Quebec (Canada), the assignee of the subject patent application, and work in the area of Signal Processing and DSP for this company. I have a Ph.D. in Electrical Engineering from McMaster University, and am skilled in the art of radio communications technologies.

3. I have been asked to review U.S. Patent No. 5,402,451 (Kaewell, Jr. et al.) (hereinafter referred to as "**Kaewell**") and comment on the digital post-detection FM Spatial Diversity Combination Circuit described in that patent as compared with the spatial diversity receiver combiner of the above-identified U.S. patent application No. 09/626,593 (hereinafter referred to as the "subject application"), the content of which I am knowledgeable of.

4. Most if not all diversity schemes have the same goal. They use a greater portion of one of a set of noise contaminated signals when the signal-to-noise ratio of that signal is better than the other signal-to-noise ratios. Hereinafter, I shall refer to a more specific case of such a

system having two radio receivers with antennas sufficiently spaced apart providing signals with uncorrelated noise. For such a system, most diversity schemes use only one of the input signals when the other one is sufficiently degraded by noise. This category of diversity schemes is known as "switching diversity" because, upon implementation, only the signal with the strongest signal-to-noise ratio is used. Also, many diversity schemes apply an averaging process when the signal-to-noise ratios of the two input signals are equal whereby 50% of each of the two signals is used. Alternatively, many diversity schemes apply maximum ratio combining whereby both of the input signals are used in proportion to their respective signal-to-noise ratios.

5. Hence, it is the method used to implement a change of selection of one input signal to the other, when their signal-to-noise ratios change, so that the better signal is selected, which differentiates between different diversity schemes.

6. In the following I shall compare the signal combining method of the subject application with that described in **Kaewell**. The two are similar to the extent that each has the following general characteristics. Both methods incorporate linear combining and both provide a combiner comprising an adder fed by two gain stages applied to the input signals. And, the gains applied to each input signal are complementary, meaning that if the diversity ratio, α, is defined to be the gain applied to signal #1, then the gain applied to signal #2 will be (1-α). But it is in these general characteristics that the similarities between the two combiners end. When one considers the particular methods applied to determine the diversity ratio, it is evident that they are very different.

7. The combining method of the subject application implements α as the proportion of a fixed margin the difference in power between the two signals has. More specifically, the diversity ratio of the combiner of the subject application is defined according to equations (1), (2) and (3) below for a margin of 6dB:

$$\alpha = 0.5 + \frac{10 * \log\left(\frac{P_1}{P_{ref}}\right) - 10 * \log\left(\frac{P_2}{P_{ref}}\right)}{2 * \text{margin}} \qquad \text{for } -6\text{ dB} < (\text{P1-P2})\text{ (dB)} < 6\text{ dB} \qquad (1)$$

$$\alpha = 0 \qquad \text{for (P1-P2)(dB)} < -6\text{ dB} \qquad (2)$$

$$\alpha = 1 \qquad \text{for (P1-P2)(dB)} > 6\text{ dB} \qquad (3)$$

8. From the foregoing equations (1), (2) and (3), it can be seen that if the powers of the input signals are equal, the diversity ratio, α, will be 0.5. Also, if one of the signals is 6 dB stronger than the other, then only that stronger signal is used. If the difference in power between the two signals is less than 6dB, then the diversity ratio, α, takes an intermediate value that varies, linearly, between the two end points, P1-P2 = -6 dB, α = 0 and P1-P2 = 6dB, α = 1. Further, it is to be noted that if the noise level is constant, the power level is representative of the signal-to-noise ratio.

9. The advantages of the foregoing combining method in the subject application are: (i) it is straightforward to implement: (ii) it works regardless of the absolute power levels involved; and (iii) it provides a diversity gain close to the optimal diversity combining.

10. In contrast, the combining method described by **Kaewell** represents a totally different implementation. The diversity ratio of **Kaewell** is derived from the unsigned logarithm of the power of the input signals. This means that P_1 and P_2 must be greater than the log reference $P_{ref.}$ According to the combining method of **Kaewell**, the diversity ratio, α, is defined according to equations (4) and (5) below:

$$\alpha = \frac{10*\log\left(\frac{P_1}{P_{ref}}\right)}{10*\log\left(\frac{P_1}{P_{ref}}\right)+10*\log\left(\frac{P_2}{P_{ref}}\right)} \tag{4}$$

Or equivalently:

$$\left(2-\frac{1}{\alpha}\right)*10*\log(P_{ref}) = 10*\log(P_2)+\left(1-\frac{1}{\alpha}\right)*10*\log(P_1) \tag{5}$$

11. It is evident from the foregoing equation (5) that, unlike the diversity ratio of the subject application, the diversity ratio, α, of **Kaewell** does not depend only on the difference of power in dB but, instead, must also depend on the absolute power values of the signals. Furthermore, as illustrated by the graphs of Figure 1 (depicting the diversity combining of the subject application) and Figure 2 (depicting the diversity combining described by **Kaewell**), of Appendix A attached hereto, the lower the reference level of **Kaewell** is, the less sensitive will be **Kaewell**'s diversity ratio to a difference in power between the

input signals. In Figures 1 and 2 the x and y axes are the absolute power of signal #1 and the difference of power between signal #'s 1 and 2, respectively. The z axis is the corresponding diversity ratio. Figure 2 clearly shows that **Kaewell**'s diversity ratio depends largely on the absolute power of the signals. For instance, at –40dBm, it would take much more than 10 dB of difference between the input signal powers in order for the diversity ratio, α, of **Kaewell** to be significantly different than 0.5. In turn, this means that the range in which the combining method of **Kaewell** performs well is limited, as compared to that of the combiner of the subject application.

12. I conclude that although the each subject application and **Kaewell** can be said to be similar, in that both describe diversity methods that use a linear combiner, these similarities are largely superficial. Substantively, they differ greatly in the methods by which their diversity ratios are calculated. The method of the subject application is not computation intensive, yet provides the advantages of switching diversity while approaching the optimal performance of maximum ratio combining. **Kaewell**'s method may be easy to implement using integrated circuits such as FM IF chips that provide a RSSI log signal but a drawback of this method is that it only does an acceptable job for signals approaching the lower end of the power range set by the FM IF chips.

13. The following simple example illustrates how differently the two methods would handle a typical real-life situation. Two data signals are received from mobile transmitters through a Rayleigh fading channel. At a given moment, signal #1 has a rather constant power at around –60 dBm while signal #2 is affected by a fade reducing its amplitude to –65 dBm. The combiner method of the subject application would apply a diversity ratio of 0.92 (calculated as 92% of signal #1 and 8% of signal #2) whereas **Kaewell** would apply a diversity ratio of 0.52 (calculated as 52% of signal #1 and 48% of signal #2), given a reference of –120 dBm. This result provided by **Kaewell** is not desirable since, given the difference in power, the accepted (conventional) teaching of diversity theory dictates that more of the higher SNR signal should be used. On the other hand, the result provided by the present application does accomplish this goal to a much greater extent than **Kaewell**.

14. The foregoing example, and the illustrations of Figures 1 and 2 of Appendix A hereto, demonstrate the superiority of the combiner of the subject application.

15. In my opinion, this superiority of the combiner of the subject application provided by the diversity ratio applied thereby is unobvious to one skilled in the art.

16. I, the undersigned, declare that these statements were made with the knowledge, and having being warned, that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and that such willful false statements may jeopardize the validity of the application or any patents issuing thereon; and, further, declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true.

Date of Signature: July 5, 2004.

By: JRLarocque

Dr. Jean-Rene Larocque, Ing.

APPENDIX A

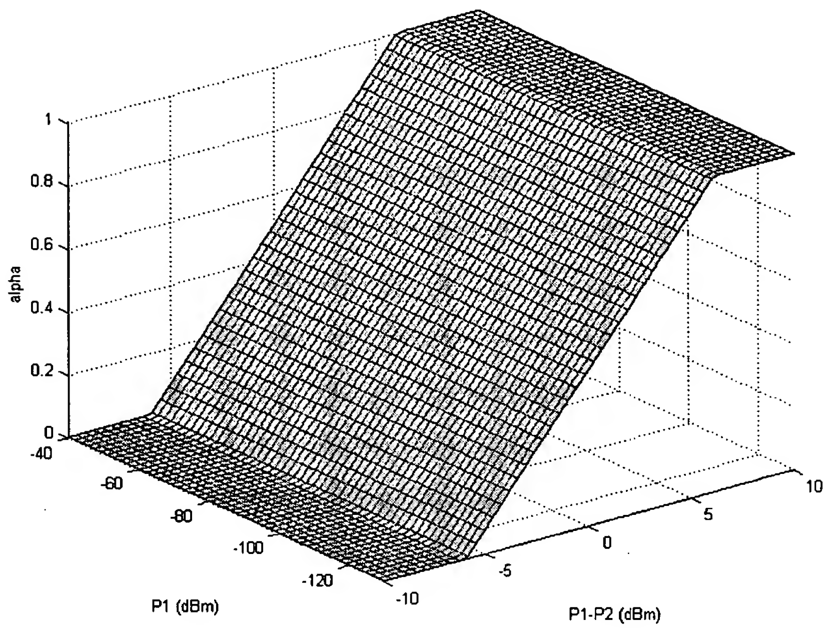

Figure 1 – Diversity Combining Ratio Using Dataradio Rule

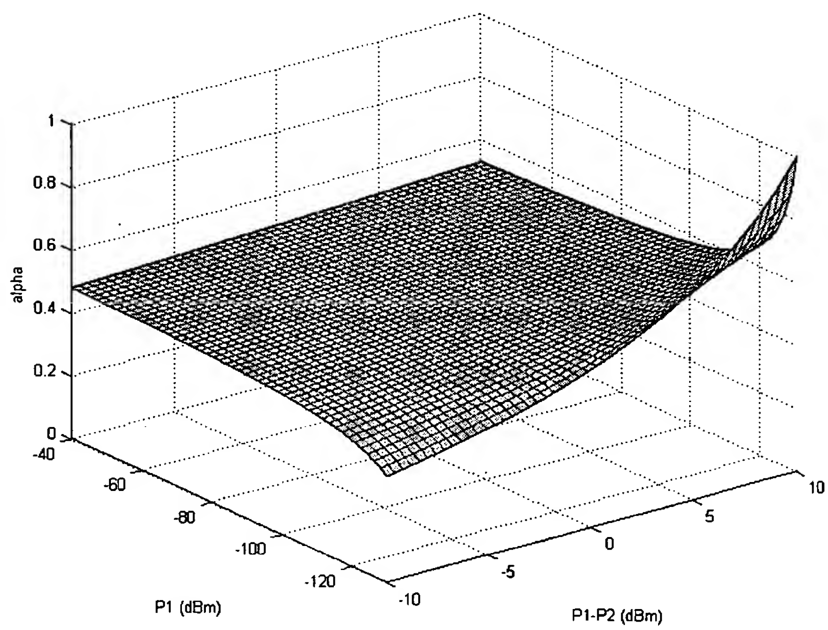

Figure 2 – Diversity Combining Ratio Using Kaewell Rule (P_{ref}=-140 dBm)